



NEWTON'S **APPLE**[®] *Multimedia*

Reflection



Infrared

Teacher's Guide



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Reflection



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Infrared



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Introduction

Welcome to the *Newton's Apple Multimedia Collection*™!

Drawing from material shown on public television's Emmy-award-winning science series, the multimedia collection covers a wide variety of topics in earth and space science, physical science, life science, and health. The *Newton's Apple Multimedia Collection* contains a CD-ROM, a printed Teacher's Guide, a video with two Newton's Apple® segments and a scientist profile, and a tutorial video.

The Teacher's Guide provides three inquiry-based activities for each of the topics, background information, assessments, and a bibliography of additional resources.

The CD-ROM holds a wealth of information that you and your students can use to enhance science learning. Here's what you'll find on the CD-ROM:

- two full video segments from *Newton's Apple*
- additional visual resources for each of the *Newton's Apple* topics
- background information on each topic
- a video profile of a living scientist working in a field related to the *Newton's Apple* segments
- an Adobe Acrobat® file containing the entire teacher's manual along with student reproducibles
- UGather® and UPresent® software that allows you and your students to create multimedia presentations
- QuickTime® 3.0, QuickTime® 3 Pro, and Adobe Acrobat® Reader 3.0 installers in case you need to update your current software

The *Newton's Apple Multimedia Collection* is designed to be used by a teacher guiding a class of students. Because the videos on the CD-ROM are intended to be integrated with your instruction, you may find it helpful to connect your computer to a projection system or a monitor that is large enough to be viewed by the entire class. We have included a videotape of the segments so that you can use a VCR if it is more convenient. Although the CD-ROM was designed for teachers, it can also be used by individuals or cooperative groups.

With the help of many classroom science teachers, the staff at *Newton's Apple* has developed a set of lessons,

activities, and assessments for each video segment. The content and pedagogy conform with the National Science Education Standards and most state and local curriculum frameworks. This Teacher's Guide presents lessons using an inquiry-based approach.

If you are an experienced teacher, you will find material that will help you expand your instructional program. If you are new to inquiry-based instruction, you will find information that will help you develop successful instructional strategies, consistent with the National Science Education Standards. Whether you are new to inquiry-based instruction or have been using inquiry for years, this guide will help your students succeed in science.

NATIONAL SCIENCE EDUCATION STANDARDS

The *National Science Education Standards* published by the National Research Council in 1996 help us look at science education in a new light. Students are no longer merely passive receivers of information recorded on a textbook page or handed down by a teacher. The Standards call for students to become active participants in their own learning process, with teachers working as facilitators and coaches.

Our goal is to provide you with sound activities that will supplement your curriculum and help you integrate technology into your classroom. The activities have been field tested by a cross section of teachers from around the country. Some of the activities are more basic; other activities are more challenging. We don't expect that every teacher will use every activity. You choose the ones you need for your educational objectives.



Teacher's Guide

We suggest you take a few minutes to look through this Teacher's Guide to familiarize yourself with its features.

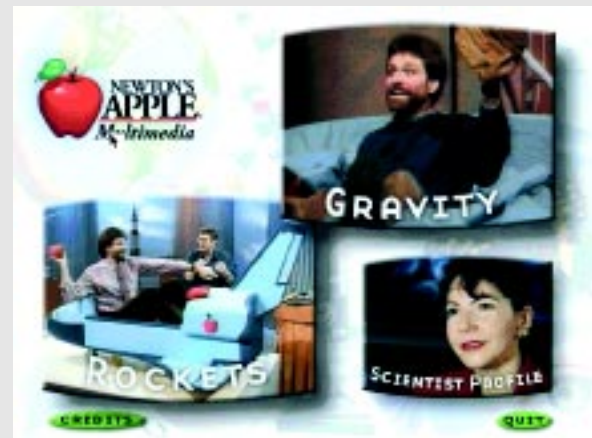
Each lesson follows the same format. The first page provides an overview of the activity, learning objectives, a list of materials, and a glossary of important terms. The next two pages present a lesson plan in three parts: ENGAGE, EXPLORE, and EVALUATE.

- ENGAGE presents discussion questions to get the students involved in the topic. Video clips from the *Newton's Apple* segment are integrated into this section of the lesson.
- EXPLORE gives you the information you need to facilitate the student activity.
- EVALUATE provides questions for the students to think about following the activity. Many of the activities in the collection are open-ended and provide excellent opportunities for performance assessment.

GUIDE ON THE SIDE and TRY THIS are features that provide classroom management tips for the activity and extension activities.

USING THE CD-ROM

When you run the *Newton's Apple* CD-ROM, you will find a main menu screen that allows you to choose either of the two *Newton's Apple* topics or the scientist profile. Simply click on one of the pictures to bring up the menu for that topic.



Main Menu

Once you have chosen your topic, use the navigation buttons down the left side of the screen to choose what information you want to display.



Topic Menu

The Background button brings up a short essay that reviews the basic science concepts of the topic. This is the same essay that is in the Teacher's Guide.



PLAYING THE VIDEO

The Video button allows you to choose several different clips from the video segment. We have selected short video clips to complement active classroom discussions and promote independent thinking and inquiry. Each video begins with a short introduction to the subject that asks several questions. These introductory clips can spark discussion at the beginning of the lesson. The Teacher's Guide for each activity presents specific strategies that will help you engage your students before showing the video. Each of the individual clips are used with the lesson plans for the activities. The lesson plan identifies which clip to play with each activity.



Video Menu

Once you select a video and it loads, you'll see the first frame of the video segment. The video must be started with the arrow at the left end of the scroll bar. As you play the video, you can pause, reverse, or advance to any part of the video with the scroll bar. You can return to the Clips Menu by clicking on the Video button.

Multimedia Tools

The *Newton's Apple* staff wants you to have a product that is flexible so that you can use it in many different ways. All of the video clips used in the program are available to you for display outside the program. You may combine them with other resources to create your own multimedia presentations. You will find all the video clips in folders on the CD-ROM. You are free to use these clips in any way you like for classroom use only. They cannot be repackaged and sold in any form without written permission of *Newton's Apple*.

You will also find a folder for UGather® and UPresent®. These two pieces of software were developed by the University of Minnesota. They allow you to create and store multimedia presentations. All of the information for installing and using the software can be found in the folder. There is an Adobe Acrobat® file that allows you to read or print the entire user's manual for the software. We hope you will use these valuable tools to enhance your teaching. Students may also wish to use the software to create presentations or other projects for the class.



Technical Information

Refer to the notes on the CD-ROM case for information concerning system requirements. Directions for installing and running the program are also provided there.

Make sure you have the most current versions of QuickTime® and Adobe Acrobat® Reader installed on your hard drive. The installation programs for QuickTime 3, QuickTime Pro, and Acrobat Reader 3.0 can be found on the CD-ROM. Double-click on the icons and follow the instructions for installation. We recommend installing these applications before running the *Newton's Apple Multimedia* program.

Trouble Shooting

There are several Read-Me files on the CD-ROM. The information found there covers most of the problems that you might encounter while using the program.

INTEGRATING MULTIMEDIA

We suggest that you have the CD-ROM loaded and the program running before class. Select the video and allow it to load. The video usually loads within a couple of seconds, but we recommend pre-loading it to save time.

All of the video segments are captioned in English. The captions appear in a box at the bottom of the video window. You can choose to play the clips in either English or Spanish by clicking one of the buttons at the bottom right of the screen. (You can choose Spanish or English soundtracks for the scientist profile.)

The Resources button provides you with four additional resources. There are additional video clips, charts, graphs, slide shows, and graphics to help you teach the science content of the unit.



Resources Menu

The other navigation buttons on the left side of the window allow you to go back to the Main Menu or to exit the program.



Reflection Teacher's Guide

Here's Looking at Me

What is a mirror? What is the difference between the image you see in the mirror and the real object? How does a mirror reflect light? What is the law of reflection and how does it apply to different types of mirrors?

Themes and Concepts

- light and light waves
- reflection
- properties of reflective surfaces

National Science Education Content Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.

Content Standard B: Students should develop an understanding of motions and forces and transfer of energy.

Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. Front and Back—approx. 15 min. prep; 45 min. class time

How does the virtual image in a mirror relate in size to the real object? How far is a virtual image from the real object? Using a flat mirror, a ruler, and a penny, students discover the relationship between the virtual image in a mirror and the real object.

2. The Angle Tangle—approx. 20 min. prep; 45 min. class time

How do individual light rays reflect off a mirror? Are there any special laws that control the bounce of a beam of light off a shiny surface? Students discover the law of reflection using a flat mirror, a protractor, and a light ray simulator.

3. Throwing a Curve—approx. 20 min. prep; 45 min. class time

Why do curved mirrors distort a reflection? Is there any way to predict how an image will change in a curved mirror? Students use a light ray simulator and a curved reflector to discover the relationship between the bend in a mirror and the angle of reflection.



More Information

Internet

Newton's Apple

<http://www.ktca.org/newtons>

(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

Laws of Reflection -

Saskatchewan Education Dept.

<http://www.sasked.gov.sk.ca/docs/physics/u3b12phy.html>

(Good resource on the background of the laws of reflection. Includes teaching suggestions, activities, and demonstrations.)

Diffuse Reflection Items -

Hamburg Technical University

<http://uranus.mt2.tu-hamburg.de/~rb/Docs/povray/node122.html>

(Excellent overview on the subject of the diffuse reflection of light.)

Light and Optics -

University of Oregon

http://guernsey.uoregon.edu/~phdemo/demo/Light_and_Optics/LO-Optics.html

(Good demonstrations on the reflection of light and mirrors. Excellent diagrams included.)



Reflection

Internet Search Words

mirrors
optics
reflection of light

Books and Articles

Cassidy, J. *Explorabook*. Palo Alto, CA: Klutz Press, 1991.
(A super source of fun activities using mirrors and light waves.)

DiSpezio, M. *Visual Foolery*. Reading, MA: Planet Dexter (Addison-Wesley), 1995.
(Many hands-on activities with mirrors and optical illusions.)

Evans, H. (1996, May) "Ray Tracing With Hinged Mirrors," *The Physics Teacher*. v34, n5.
(Deals with the law of reflection.)

Gardner, R. *Experiments With Light and Mirrors*. Springfield, NJ: Enslow Publishers, 1995.
(A fine source of hands-on experiments dealing with mirrors and the reflection of light.)

National Council of Teachers of Mathematics, (1996, May) "Mirror, Mirror on the Wall," *Teaching Children Mathematics Magazine* v2 n9.
(A great lesson on the use of mirrors in plane geometry.)

Tomecek, S. *Bouncing & Bending Light*. New York: W.H. Freeman, 1995.
(Reviews the basics of how mirrors work, the law of reflection, the history of mirrors, and common uses of mirrors)

Zubrowski, B. *Mirrors: Finding Out About the Properties of Light*. New York: Morrow Junior Books, 1992.
(A good basic resource on mirrors and reflection.)

Community Resources

Science museums
Local college or university physics departments

Background

Mirror, mirror on the wall, why do you bother to reflect at all? Over the years, mirrors have been thought of as bringers of both good luck and bad luck. They were often looked at as being the "window to the soul." But the reflection you see in a mirror is merely the result of light waves interacting with a very smooth, shiny surface.

When light hits a surface, one of four things can happen: 1. It can pass through the surface; 2. it can be absorbed, or soaked up, by the surface; 3. it can bend, or refract as it passes through a surface; 4) it can reflect, or bounce off of the surface back toward the observer. In fact, most people don't realize it, but without reflection, you couldn't see anything. Have you ever been in a totally dark room with absolutely no light? Everything in the room is invisible because there is no light to reflect back to your eye.

So if light is reflecting off everything you see, why can't you see your reflection in the page of a book or in the palm of your hand? It's because these surfaces are rough. When light hits them, all of the rays bounce off in different directions and are scattered. Scientists call this type of reflection "diffuse reflection," because the light bouncing off the surface is diffused or spread out. In order for an object to reflect like a mirror, all of the light rays that hit it have to bounce off at the exact same angle. To do this, the surface has to be extremely smooth. This type of reflection is known as *regular* or *specular* reflection.

You may have noticed your reflection in a still pond or a puddle on a calm sunny day. That's because the surface of the water is smooth. If the wind starts blowing, your image begins to break up because the little waves on the surface make the water rough. In scientific terms, the light that was reflecting in a specular manner became diffuse. When the water calms down again your image will reappear.

Water isn't the only material that occasionally reflects light like a mirror. Smooth shiny metal, a clean plate, a freshly polished table top, and the screen of your television set all make fairly good mirrors from time to time.

Whether it's a mirror, a window, or the bumper on your friend's car, all smooth, polished surfaces reflect light according to the law of reflection. This rule is often stated that when a light ray strikes a mirror surface, the angle of incidence equals the angle of reflection. Simply put, whatever angle a ray of light hits a mirror, it will bounce off the mirror at the exact same angle, but in the opposite direction.

So, the next time you pass a mirror, reflect for a moment on how it works!



Video & Stills

Video Segments

Introduction

41:10 to 41:43—Newton's host Dave Huddleston reflects about the images in mirrors. (33 sec.)

Video Clip 1

41:50 to 43:18—Movie actress Shelly Duvall observes that the image in a mirror is the same distance from the front of the mirror as the real object. (1 min. 28 sec.)

Video Clip 2

43:18 to 44:12—Shelly Duvall explains how the image in a mirror appears to be reversed. (54 sec.)

Video Clip 3

44:12 to 44:58—Shelly Duvall discusses the law of reflection and demonstrates how the angle of incidence always equals the angle of reflection for a ray of light. (46 sec.)

Video Clip 4

44:59 to 46:13—Shelly Duvall shows how a curved mirror also follows the law of reflection, but because of the shape of its surface, the image produced is warped. (1 min. 14 sec.)

Multimedia Resources

Button A

Video: *Newton's Apple* host Peggy Knapp demonstrates optical illusions with symmetry and mirrors.

Button B

Video: *Newton's Apple* host Peggy Knapp uses billiard balls and a pool table to demonstrate the law of reflection.

Button C

Video: A simple animation from *Newton's Apple* showing how light reflects off a curved surface.

Button D

Illustration: Mirrors on the Hubble Space Telescope.

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the *Newton's Apple* video segment and the background section in this guide. The assessment does not require completing all of the activities. The Unit Assessment may be used as a pre- or post-test. However, students should view the complete *Newton's Apple* video before doing this assessment. There is additional assessment at the end of each activity.

Think about it

1. The angle at which a ball hits a flat surface is the same angle that the ball will bounce off the surface, provided the ball is not spinning. The same is true for light bouncing off a reflective surface.
2. The virtual image will appear to be the same distance from the surface of the mirror as the real object. The size's of the virtual object and the real object are the same.
3. The light rays leaving the surface of a concave mirror will converge. The light rays leaving the surface of a convex mirror will spread apart. The light rays leaving the surface of a flat mirror neither spread nor converge.
4. A mirror does not change the lettering in any way. The mirror merely obeys the laws of reflection, sending the images back to your eyes as they hit the mirror. The image appears reversed, because you turn the image around to "show" it to the mirror.
5. A virtual image appears reversed to a person viewing it in a mirror. It appears reversed because you must turn the original image around so it faces the mirror. A photo graphic image is not reversed.

What would you say?

6. b 7. a 8. c 9. c 10. a



Unit Assessment

What do you know about mirrors and reflection?

Answer these questions in your journal or on a separate sheet of paper.

Think about it

1. In what way is light reflecting off a mirror similar to a ball bouncing off a wall?
2. How is a virtual image in a flat mirror similar to the real object?
3. How is the reflection off a curved mirror different than the reflection off a flat mirror?
4. What does a mirror do to make letters appear reversed?
5. How is a photographic image different from a virtual image in a mirror?

What would you say?

6. If you look into a mirror and your face appears to be stretched out, what's probably wrong with the mirror?
 - a. The mirror is dirty.
 - b. The mirror is curved.
 - c. The mirror is cracked.
 - d. The mirror is made out of plastic.
7. If you're standing 5 feet in front of a mirror, how far should your reflection appear to be behind the mirror?
 - a. 5 feet.
 - b. 10 feet.
 - c. Your reflection should be in front of the mirror.
 - d. 25 feet.
8. If you shine a flashlight directly into a mirror at a 90 degree angle, which way will the beam of light be reflected?
 - a. To the left.
 - b. To the right.
 - c. Straight back at the flashlight.
 - d. It won't be reflected at all.
9. Which statement best describes the "law of reflection"?
 - a. The angle of incidence is less than the angle of reflection.
 - b. The angle of incidence is greater than the angle of reflection.
 - c. The angle of incidence equals the angle of reflection.
 - d. Light can only reflect off of flat mirrors.
10. Which of the following statements is false? When you press your hand on a mirror —
 - a. the image of your hand will be smaller than your hand.
 - b. your hand appears opposite the way your friend would see it if you were holding it up to them.
 - c. the image of your hand will be the same size as your hand.
 - d. the image will appear smaller as you move our hand away from the surface of the mirror.



Activity 1

Front and Back

What is a virtual image? How does the size of a virtual image compare to the size of the object in front of the mirror? Are the real object and the virtual image the same distance from the surface of the mirror?

Getting Ready

Overview

Students investigate the properties of mirrors and virtual images. Using a flat mirror, a ruler, and a penny, students discover the relationship between the virtual image in a mirror and the real object.

Objectives

After completing this activity, students will be able to—

- compare the qualities of a real object and its virtual image
- explain how the distance to the virtual image in a mirror relates to the real object it is reflecting.

Time Needed

Preparation: approximately 15 minutes

Classroom: approximately 45 minutes

Materials

For the teacher:

- large, flat, rectangular mirror

For each group of students:

- small, flat, rectangular mirror
- penny
- 30 cm ruler with mm gradations
- pencil
- plain sheet of 8.5" x 11" paper

Important Terms

reflection — The image of an object that you see in a mirror. Mirrors are able to reflect images because mirrors reflect light.

refract — To bend light. When light passes from one substance to another—such as from water to air or through a prism—it refracts or bends.

virtual image — The image that you see in a mirror.



Reflection

Here's How

Video Clip 1

41:50 to 43:18

Movie actress Shelly Duvall observes that the image in a mirror is the same distance from the surface of the mirror as the real object. (1 min. 28 sec.)

Video Clip 2

43:18 to 44:12

Shelly Duvall explains how a mirror appears to reverse an image. (54 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [41:10 to 41:49]. Find out what students already know about reflection. As a class, discuss the questions posed by Dave Huddleston.
- Remind students to hold the mirror perpendicular to the paper. Ask them to think of what might happen to their results if they were to tilt the mirror forward or backward.
- Judging the distance of an object behind the mirror is a bit tricky. Ask students to think of some way that might help them make their measurement.
- All the measurements are done on a horizontal plane. Could students conduct the experiment with the mirror lying flat on the table and holding the penny above it? What would be some of the drawbacks associated with doing the experiment in this fashion? Have them try it and compare the results to the first set of data.
- If it is appropriate, view the entire *Newton's Apple* video segment on reflection after completing the activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 1 for each student.
- Review the information in the Background on page 8.

Engage (Approx. 15 minutes)

Hold up a large mirror and ask students to describe some of the characteristics of reflections in the mirror. Have them pay particular attention to the size, shape, and color of the reflections compared to the objects making them. Ask students for similarities and differences between the image and the real object. Accept all responses.

Show Video Clip 1 [41:50 to 43:18] in which Shelly Duvall observes that the image in a mirror—the virtual image—appears the same distance from the surface of the mirror as the real object. Ask the students to think of how they could check if this is true. Accept all suggestions. Ask them how Shelly Duvall proves it to herself.

Ask students if they have ever tried to read anything in a mirror. Ask them what happens to letters of the alphabet. Show Video Clip 2 [43:18 to 44:12]. Discuss Shelly's explanation about the reversal of an image in a mirror.

Explore (Approx. 30 minutes)

Tell students that they will work in groups to measure the distance to the virtual image in a mirror. By using an object to sight on the virtual image, they will be able to estimate how far behind the mirror the virtual image appears to be.

Have the students work together in small groups. Begin by folding a blank sheet of paper in half so that there are two equal sections 8.5" x 5.5" in size. Tell students to draw a line across the paper at the fold and hold the paper so that the line in the fold crosses from left to right. Using the metric ruler, have the students measure and draw lines at 2-cm increments from the center line to the end of the sheet of paper. The lines will be at 2, 4, 6, 8, 10, and 12 cm.



Activity 1

With the paper lying flat on a table, have the students place the mirror on the center line so that the mirror is perpendicular to the paper and table. Students will see a “virtual scale” in the mirror. Tell students to leave a 4-cm margin along the right edge of the paper so that they can see the edge of the paper as it extends behind the mirror.

Tell students to place the penny at the 4-cm mark in front of the mirror. Have them lay a pencil flat on the right edge of the paper so that it is in line with the mirror. Next, using their depth perception to guide them, students slowly roll the pencil back along the right-hand side of the paper and stop when they feel that the pencil is in direct line with the virtual image “behind” the mirror. Students mark this point on the paper and use a ruler to measure the distance from the center line. Tell students to record the measurement in their journals and then repeat the activity with the penny at the 8- and 12-cm marks.

Evaluate

1. What happens to the size of the virtual penny as you move the real penny further away from the mirror. (The virtual penny gets smaller.)
2. How does the distance measured to the virtual penny compare with the distance that the real object is in front of the mirror? (The two distances are equal.)
3. If you placed the penny head-side-up, which direction would Abraham Lincoln be facing? (The virtual image would be facing left.)

Try This

Construct mirrors using aluminum foil, plastic plates, or other shiny surfaces. Do these mirrors follow the same rules for a virtual image as a real mirror? How are they different?

Try to produce multiple reflections by using two mirrors. Experiment with the mirrors to create different effects, such as the appearance that the reflections go on forever. Figure out how the virtual image rule applies to your discovery. Share your experiment and observations with the class.

Architects and designers have used mirrors to change the appearances of a room. For example, mirrored walls are often used to make a small room look larger. Investigate the use of mirrors in buildings to learn other applications of mirrors in architecture. Report your findings to the class.

FRONT AND BACK

Activity Sheet 1

NAME _____

CLASS PERIOD _____

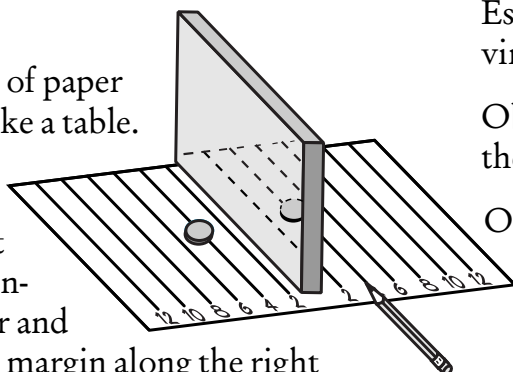
WHAT YOU'RE GOING TO DO

You are going to investigate how the depth of a virtual image in a mirror relates to the distance of the real object from the surface of the mirror.

HOW TO DO IT

1. Work with your group. Begin by folding a blank sheet of paper in half. Next, draw a line across the paper at the fold. Using a metric ruler, measure and draw lines at 2-cm increments from the center line to the end of the sheet of paper. The lines will be at 2, 4, 6, 8, 10, and 12 cm.

2. Place the sheet of paper on a level surface like a table. Hold the mirror on the center line of the paper so that the mirror is perpendicular to the paper and table. Leave a 4-cm margin along the right edge of the paper so that you can see the edge of the paper as it extends behind the mirror. You will be able to see the "virtual scale" in the mirror.



3. Put a penny at the 4-cm mark in front of the mirror. Lay the pencil flat on the paper so that it is in line with the mirror. Then, slowly roll the pencil back along the right hand side of the paper and stop when you think that the pencil is in direct line with the virtual image of the penny behind the mirror. Mark this point on the paper. Measure the distance from the center line to the point marking the location of the virtual image. Record the measurement in your journal. Repeat the activity with the penny at the 8- and 12-cm marks.

RECORDING YOUR DATA

Set up a data table in your journal to record your measurements and other observations. The data table should include the following kinds of information for each trial.

Distance of the penny from the front of the mirror

Estimated distance (distance of pencil mark) of virtual image behind mirror

Observed distance of the virtual image behind the mirror

Other observations

WHAT DID YOU FIND OUT?

How does the distance of a penny in front of a mirror compare to the depth of its virtual image in the mirror?

How accurate were your estimations? Was there a difference in accuracy as the distance of the penny from the mirror increased? What might account for the difference between the estimate and the observed distance?

Repeat the experiment using other objects of different sizes. Does each of them produce the same relationship?



Activity 2

The Angle Tangle

How does light reflect off a mirror? What is the law of reflection? What happens to light that strikes a mirror at a 90-degree angle?

Getting Ready

Overview

Students learn how the law of reflection works. Using a simple light ray device, a protractor, and a flat mirror, students make observations and take measurements to test the law of reflection.

Objectives

After completing this activity, students will be able to—

- explain the law of reflection as it applies to mirrors
- measure the angles of incidence and reflection for light
- predict the angle of reflection for a beam of light striking the surface of a flat mirror

Time Needed

Preparation: approximately 20 minutes

Classroom: approximately 45 minutes

Materials

For the teacher:

- smooth, flat wall
- handball or similar bouncy ball
- metric ruler

For each group of students:

- flashlight
- protractor
- comb
- 6 inches of duct tape or electrical tape
- pencil
- small, flat, rectangular mirror
- copy of the template

Important Terms

angle of incidence — The angle at which a ray of light strikes the surface of a mirror.

angle of reflection — The angle at which a ray of light bounces off the surface of a mirror.

symmetry — A balanced arrangement of parts on either side of a line or center point.



Reflection

Here's How

Video Clip 3

44:12 to 44:58

Movie actress Shelly Duvall explains the law of reflection and demonstrates how, for a ray of light, the angle of incidence always equals the angle of reflection. (46 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [41:10 to 41:49]. Find out what students already know about reflections. As a class, discuss the questions posed by Dave Huddleston.
- During the Engage portion of the lesson, you may wish to show the video clip found at Resource Button B. This clip shows the angles of incidence and reflection using a billiard table.
- Before starting the activity, you may wish to review how to measure angles using a protractor.
- To have the activity work most effectively, make the room as dark as possible.
- Ask the students to think about how the results might change if the mirror were not placed directly on top of the line. Would the angle readings be accurate? Why or why not?
- Once the students have traced and measured a few light rays, have them try the opposite. Have them draw a line to the mirror representing incident light and then predict where the reflected ray will go. Use the flashlight to check the predictions.
- If it is appropriate, view the entire *Newton's Apple* video segment on Reflection after completing the activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Prepare and copy the template for the student activity.
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 2 for each student.
- Review the information in the Background on page 8.

Engage (Approx. 15 minutes)

Ask students how many of them have played tennis or handball. Ask them how they would bounce a ball off a wall if they wanted it to come straight back at them. (You would have to throw it straight so that it hit the wall at a 90-degree angle.) Ask what would happen if you threw the ball at the wall at a smaller angle. (The ball would bounce off in the opposite direction at the same angle.)

Demonstrate angular rebound by throwing a ball against a wall at several different angles. (You may wish to perform this demonstration in a gym or outside.) Have two students stand 4 to 5 meters apart, a meter or two from the wall. Hand one of them the ball. Tell them they are to bounce the ball off the wall so that it goes to their partner. Ask how they decide what angle to throw the ball for it to bounce to the partner. Explain that the way a ball bounces off a wall is very similar to the way light bounces off a mirror. Explain that they are going to do an activity that will test this idea.

Explore (Approximately 30 minutes)

For this activity, you will need to enlarge the miniature template shown on Activity Sheet 2. The template should be large enough to fill a 8.5" x 11" sheet of paper. The "Place mirror here" line should run all the way across the top of the sheet. The "Normal line" is perpendicular to the mirror line and should be centered on the sheet. Lines A, B, C, and D should form angles of approximately 70°, 45°, 20°, and 5° to the mirror line. Make copies of the full-sized template for each group.

Separate students into groups and explain that they are going to use a protractor to measure the incident and reflected light from a specially adapted flashlight.



Activity 2

Have the groups assemble the light ray device by placing a comb over the front of a flashlight lens so that light shines through the teeth. Using the electrical tape, have students cover all the spaces except for one in the middle. This light should project a single light ray across the table when the flashlight is lying flat.

Have students place the template on a desktop. Have one member of the group hold the mirror straight up and down along the line that says “Place mirror here.” The black line that says “Normal Line” should look like it’s going straight through the mirror. If it appears bent where it strikes the mirror, students should adjust the mirror so that the line is straight.

Have students in each group turn on the flashlight and lay it flat on the table. Place it so that the comb is parallel with the line marked “A” on the activity sheet. With a pencil, have them trace the light ray as it strikes the mirror and bounces off. Label this line “A,” and repeat the procedure for spots “B,” “C,” and “D.” Students should trace down the center of the light ray.

After students have traced all four light rays, they should remove the mirror and use the protractor to measure the angle that each line makes with the mirror line. Have them measure the incident ray and reflected ray separately and record the angles on the data sheet. If time permits, have students try several additional ray angles of their own.

Ask students what they discovered. Conclude by showing Video Clip 3 [44:12 to 44:58] in which Shelly Duvall explains the law of reflection and demonstrates that the angle of incidence of light always equals the angle of reflection. An additional video clip demonstrating this principle can be found at Resource Button B.

Evaluate

1. How do your measurements for the incident and reflected rays compare with each other? What are some of the sources of error that might be skewing the results? (The two measurements should be about equal. Errors usually result from the mirrors not being exactly parallel to the line or from incorrectly traced lines.)
2. What would happen to a light ray that was directed into the mirror from a line perpendicular to the mirror? (It would come directly back into the flashlight.)
3. How does changing the distance from the flashlight to the mirror affect the way the light is reflected? (It should have no effect on the angle; however, the light ray becomes wider as the distance is increased.)

Try This

Periscopes are devices that use two mirrors set at angles parallel to each other so that a person can see an object around a corner or from below the surface of water. Construct a periscope of your own using two small mirrors and a quart-size paper milk container. The directions can be found in many books.

You may have noticed the word “ambulance” written in reverse on the front of emergency vehicles. This is so the words appear correct when viewed through the rearview mirror of the car. Mirror writing can be confusing, but it also can be fun. Try writing your name so that it appears correct when viewed in a mirror. How does the law of reflection control the way the letters are printed?

View the video clip found under Resource Button A on the CD-ROM. Think of other ways mirrors could be used to set up optical illusions. Try out some of your ideas and demonstrate them to the class.

In art, symmetry involves repeated patterns of similar design. Kaleidoscopes are devices that use mirrors set at specific angles to produce symmetrical images. Investigate how kaleidoscopes are made and then try making your own kaleidoscopic images. Experiment with changing the size of the angle between the mirrors and the number of mirrors used.

ANGLE TANGLE

Activity Sheet 2

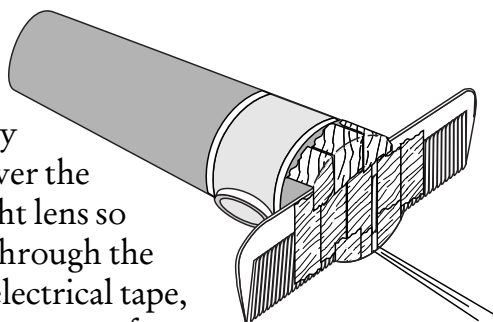
NAME _____ CLASS PERIOD _____

WHAT YOU'RE GOING TO DO

You are going to build a light ray device and use it to explore the law of reflection.

HOW TO DO IT

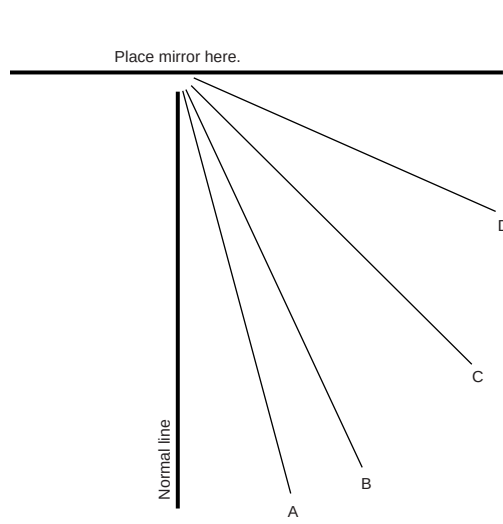
1. Work with your group and assemble the light ray device by placing a comb over the front of a flashlight lens so that light shines through the teeth. Using the electrical tape, cover all the spaces except for one in the middle.



2. Place the template on a level surface such as a tabletop. Have one member of your group hold the mirror straight up and down along the line that says "place mirror here" on the template. The "Normal Line" should look like it's going straight through the mirror. If it appears bent where it strikes the mirror, adjust the mirror so that the line is straight.

3. Turn on the flashlight and lay it flat on the table. Place it so that the comb is parallel with the line marked "A" on the activity sheet. With a pencil, trace the light ray as it strikes the mirror and bounces off. Label this line "A," and repeat the procedure for "B," "C," and "D."

4. After you have traced the lines, remove the mirror and use the protractor to measure the angle that each line makes with the mirror line. Measure the incident ray and reflected ray separately and record the angles on the data sheet.



RECORDING YOUR DATA

Set up a data table in your journal to record your measurements and other observations. The data table should include the following kinds of information for each position for the test:

Position _____

Angle of incident light _____

Angle of reflected light _____

Other observations:

WHAT DID YOU FIND OUT?

The law of reflection states that the angle of reflected light is equal to the angle of incident light. Did your group find this to be true? Explain.

Compare your results with other groups' results. What might have caused any differences in your results?



Activity 3

Throwing a Curve

Why does a curved mirror make your face look funny? Do curved mirrors reflect light the same way that flat mirrors do? Does the law of reflection apply to curved mirrors too? Do curved mirrors have any practical uses?

Getting Ready

Overview

Students discover how a curved mirror not only changes the reflection of an image, but follows the same law of reflection as a flat mirror.

Objectives

After completing this activity students will be able to —

- explain how a curved mirror reflects light
- demonstrate how the law of reflection works with a curved mirror

Time Needed

Preparation: 20 minutes

Classroom: 45 minutes

Materials

For the teacher:

- large, flexible plastic mirror at least 30 cm square
- metric ruler

For each group of students:

- flashlight
- pocket comb
- small, flexible plastic rectangular mirror
- small, flat, rectangular mirror
- pencil
- metric ruler
- protractor
- copy of the template

Important Terms

concave — A surface that is curved inward.

convex — A surface that is curved outward.

focal length — The distance to the focal point

focal point — The point at which a number of light rays converge after passing through a lens or reflecting off a mirror.



Reflection

Here's How

Video Clip 4

44:59 to 46:13

Actress Shelly Duvall shows how a curved mirror also follows the law of reflection, but because of the shape of its surface, the image produced is warped. (1 min. 14 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Prepare and copy the template for the activity.
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 3 for each student.
- Review the information in the Background on page 8.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [41:10 to 41:49]. Find out what students already know about reflection. As a class, discuss the questions posed by Dave Huddleston.
- The diagram found at Resource Button C provides a useful illustration of how light reflects off a curved surface.
- Before beginning the explore section, be sure students understand the terms concave and convex.
- In the 1400s, Leonardo da Vinci developed a new type of art called "anamorphic art". In this art form, a curved mirror is used to change a distorted image into a clear image. Have students use the information they have discovered in this activity about how curved surfaces reflect light to make an anamorphic drawing that becomes a clear virtual image.
- Flexible mirrors used for camping and backpacking work well for this activity.
- If it is appropriate, you may wish to view the entire *Newton's Apple* video segment on reflection after completing the activity.

Engage (Approx. 15 min.)

Hold up a large, rectangular, plastic mirror and move among the students so that they can see their reflections. As they are looking, gently bend in the two sides of the mirror so that the mirror is curved. Ask students what they observed. Ask the students if they think the law of reflection applies to both curved mirrors and flat mirrors. Accept all answers.

View Video Clip 4 (44:59 to 46:13) in which Shelly Duvall shows how the law of reflection applies to a curved mirror. Ask if anyone can explain why Shelly appears upside down in the spoon. Review how the curved reflector obeys the same law of reflection as a flat mirror. Ask students if they can think of any situations where a curved mirror might be better than a flat mirror. (In stores and in elevators. Also, the side-view mirrors of cars are curved.) Explain to students that they are going to use light rays and curved reflectors to explore the law of reflection and its application to curved mirrors.

Explore (Approx. 30 min.)

Prepare and photocopy this template for students. On an 8.5" x 11" sheet of paper, draw a line the length of the paper about 3 cm from the left edge. Label the line "Place the mirror here." Next, about 10 cm from the mirror line draw a 3-cm line at an angle of about 20° to the mirror line. Label the line "A."

Have students work with classmates in small groups. Demonstrate how to set up the light ray simulator by taping a comb onto the lens of a flashlight (see Explore, Activity Two). Tell students that each team is going to observe how light rays behave as they bounce off three different surfaces: a convex reflector, a flat reflector, and a concave reflector. Using a pencil, they will trace the light ray patterns and draw some conclusions about the law of reflection.



Activity 3

Have students place the template on a desktop. Have them place the flashlight and comb on the sheet at line “A.” Students place the mirror on its edge on the mirror line and have one group member hold it steady. Students have another member of the group trace the incident and reflected light ray on the activity sheet. This set of rays will be the “standard” to which the other rays will be compared. Students repeat the procedure holding a convex mirror on the mirror line. Have students make sure that they hold the mirror steady on its edge so that the reflected rays are projected onto the paper. Have students repeat the same steps with the concave side of the mirror.

Next, have students use the protractor to measure the angles on the three sets of ray patterns. If time permits have the students experiment with distances from the flashlight to the different reflectors. Sliding the reflector back and forth, they should note any changes in the ray patterns.

Evaluate

1. What did you observe about the light ray pattern from the convex reflector compared to the light reflected from the flat mirror? (The light rays from the convex mirror spread out more.)
2. What happened to the ray patterns for the three reflectors as you changed the distance between the light and the surface of the reflector? (The flat mirror stayed the same, the convex reflector spread out more, and the concave reflector brought all the rays together.)
3. Based on this activity, what can you conclude about the law of reflection and curved mirrors? (The angle of incidence still equals the angle of reflection; however, these angles are determined by how much the surface of the mirror is curved.)

Try This

Curved mirrors can be used to spread light rays out or to concentrate them into a single focal point. In the 1700s, Isaac Newton developed a telescope using concave mirrors instead of lenses to magnify images of stars and planets. Today, some of the most powerful telescopes (including Hubble) use this technology to see farther into space than ever before. Investigate the development of reflecting telescopes and see how they have changed over the years. What are some of the biggest scopes and what new “active optics” are being used in the future?

THROWING A CURVE

Activity Sheet 3

NAME _____ CLASS PERIOD _____

WHAT YOU'RE GOING TO DO

You are going to compare how light rays reflect off both curved and flat mirrors. You will test a concave reflector, a convex reflector, and a flat mirror, and measure the angle of incidence and reflection for each.

HOW TO DO IT

1. Work with your group. Your teacher will explain how to make a light ray simulator from a flashlight.
2. On a sheet of paper, place the light ray simulator 10 cm from a flat rectangular mirror. Have a classmate trace the incident and reflected light rays. This set of rays will be the standard to which the other rays will be compared. Repeat the procedure using a convex mirror. Follow the same with concave mirror.
3. Next, use a protractor to measure the angles on the three sets of ray patterns. If time permits, experiment with distances from the flashlight to the reflectors, and note any changes in the light ray patterns.

RECORDING YOUR DATA

Set up a data table in your journal to record your measurements and other observations. The data table should include the following kinds of information for each of the reflector types you are using for the test.

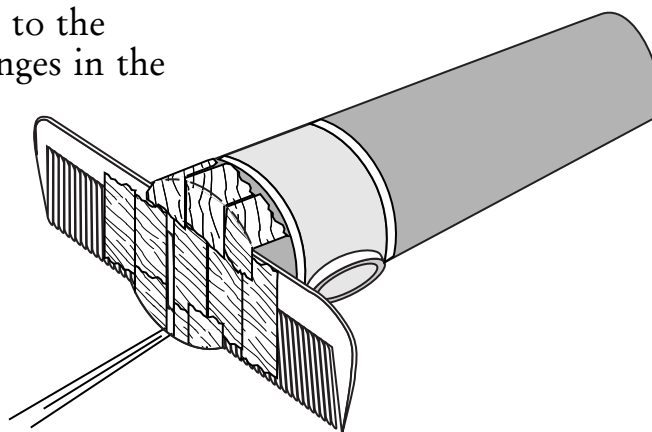
Type of reflector _____

Position _____

Angle of incident light _____

Angle of reflected light _____

Other observations:



WHAT DID YOU FIND OUT?

How do the angles of incident and reflected light from a flat surface compare with those from a curved surface?

What patterns did you observe? Do these patterns follow the law of reflection? Explain.



Infrared Teacher's Guide

Infrared Radiation

What is infrared? Is infrared light the same as infrared radiation? Is infrared radiation dangerous? Is infrared radiation red? Why can't we see infrared radiation? What can you use infrared radiation for? How do you know infrared radiation exists if it is invisible?



Themes and Concepts

- electromagnetic radiation
- electromagnetic spectrum
- wavelength and frequency
- visible light
- infrared radiation
- heat

National Science Education Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.

Content Standard B: Students should develop an understanding of the transfer of energy.

Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. Focus That Radiation—Approx. 20 min. prep; 45 min. class time

How do we know infrared radiation exists if we cannot see it? Students measure the heat generated by infrared radiation that is focused through a lens.

2. Infrared Ray Gun—Approx. 20 min. prep; 50 min. class time

How is infrared radiation similar to visible light? How is it different? Students use a TV remote control unit to explore and compare the properties of infrared and visible light.

3. As Clear as Glass—Approx. 10 min. prep; 70 min. class time

Why does the interior of a car get superheated in the sunlight? Why is it always warm inside a greenhouse? Students explore how infrared radiation passes (or doesn't pass) through glass.

More Information

Internet

Newton's Apple
<http://www.ktca.org/newtons>
(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

Infrared Astronomy—NASA
<http://www.ipac.caltech.edu/Outreach/Edu/outreach.html>
(A complete site on the subject of infrared.)

ACEPT, Patterns in Nature—
Arizona State University
<http://accept.la.asu.edu/PiN/mod/light/colorspectrum/pattLight30bj3.html>
(Learn about infrared and how it's used.)

Electromagnetic Spectrum—NASA
<http://observe.ivv.nasa.gov/nasa/education/reference/reflect/ir.html>
(A good site on understanding the structure of the electromagnetic spectrum.)

Internet Search Words

infrared
infrared astronomy
infrared satellites
electromagnetic spectrum



Infrared

Books

Ford, Brian J. *First Encyclopedia of Science*. New York: Random House, 1993.

(A good discussion of the relationship between infrared radiation and heat.)

Lafferty, Peter. *Heat and Cold*. New York: Benchmark Books, Marshall Cavendish Corporation, 1996.

(Contains a good infrared scan of a human brain and a nice description of infrared radiation.)

The Exploratorium Science Snackbook. San Francisco: The Exploratorium, 1991.

(Contains a few good descriptions of infrared experiments and museum exhibits.)

White, Laurie. *Infrared Photography Handbook*. Amherst, NY: Amherst Media, 1996.

(A practical guide to using Infrared film in your camera. Contains a number of infrared photographs.)

Wood, Robert W. *Physics for Kids—49 Easy Experiments with Heat*. Blue Ridge Summit, PA: Tab Books Inc., 1990.

(Contains a variety of simple experiments that can be done with household items.)

Background

Infrared radiation carries information from a remote control to a TV, helps us see in the dark, and keeps food warm in restaurants. What is it? In the late 1600s, Isaac Newton discovered that white light was a mixture of colors on a spectrum. It was the first step in understanding the electromagnetic spectrum, the very broad band of radiation that accounts for much of what we experience in the universe around us.

Visible light, the part of the spectrum that humans can see with the naked eye, is only one type of radiation. It makes up only a very small part of the broad electromagnetic spectrum. Our eyes aren't sensitive to the other parts of the electromagnetic spectrum, but the entire spectrum is still there. Starting with the shortest, high-frequency waves, and moving to the longest, low-frequency waves, the electromagnetic spectrum consists of: Gamma rays, X-rays, ultraviolet light, visible light, infrared radiation, microwaves, and, finally, radio waves. Although we can't see much of this radiation, there are instruments we can use to make it visible.

Infrared radiation is an important form of radiation that is used by everyone from astronomers to police. Infrared radiation is connected to heat in a very special way. As an object gets warmer, its atoms vibrate with increasing speed. A rapidly vibrating atom emits infrared radiation waves like a wiggling tadpole creates waves in a pond. When something is struck by infrared radiation, the object's atoms start to vibrate faster and faster. The object gets warmer. Increase the exposure, and it goes from warm to hot.

As atoms vibrate faster and faster, the frequency of the electromagnetic waves increases and the radiation moves up the spectrum from the infrared region into visible light. You can see this phenomenon in a toaster. As electricity flows through the heating coils, the atoms in the coils begin to vibrate. As they heat up, they emit infrared radiation. The heat grows and the vibration rate increases. Soon the "frequency" of the radiation is in the range of visible light, and the coils appear to glow red.

Infrared radiation was discovered around 1800 by British astronomer William Herschel. He found infrared radiation with a thermometer and a prism, but today infrared cameras are used. Warm objects appear brighter than cooler objects when seen through an infrared camera.

Infrared cameras are used extensively in police helicopters to search for missing persons. Similar cameras permit nighttime navigation and enemy location in military combat vehicles. Weather satellites use such cameras to better monitor changing weather patterns and the Hubble Space Telescope can study newly formed stars through a special infrared camera.

The more you learn about infrared radiation, the more you begin to realize that science covers a whole spectrum of ideas!



Video & Stills

Video Segments

Introduction

46:28 to 47:11—*Newton's Apple* host Eileen Galindo poses some interesting questions about infrared radiation. (43 sec.)

Video Clip 1

47:14 to 49:02—David Heil and Dr. Paul Kruse take a look at infrared radiation. (1 min. 12 sec.)

Video Clip 2

51:04 to 53:17—David Heil and Paul Kruse discuss practical applications of infrared radiation. (2 min. 13 sec.)

Video Clip 3

50:08 to 51:04—Maj. Matt Ferrin shows film of moving vehicles taken through an infrared “thermal sight” on a tank. (56 sec.)

Video Clip 4

49:02 to 50:03—David Heil and Paul Kruse discuss infrared radiation, visible light, and the electromagnetic spectrum. (1 min. 1 sec.)

Additional Resources

Button A

Diagram: A chart showing the electromagnetic spectrum.

Button B

Picture: Satellite photos of San Antonio, TX, taken by an infrared camera.

Button C

Picture: Infrared photo of a person holding a lit match.

Button D

Video: Infrared image of David Heil's face.

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the *Newton's Apple* video segment and the Background section in this guide. The assessment does not require completing all of the activities. The Unit Assessment may be used as a pre- or post-test. However, students should view the complete *Newton's Apple* video before doing this assessment. There is additional assessment at the end of each activity.

Think about it

1. View the person with the camera; if someone had a fever, his or her face would glow brighter than other people's faces because it would be warmer.
2. Clothing that covers your entire body—head and hands included—and insulates well would make you less visible to an infrared camera.
3. Answers will vary, but should deal with the infrared camera's sensitivity to heat radiation rather than to light. Sample answer: An exterminator could use it to find a mouse nest inside a wall.

4. All cold-blooded animals are dependent on infrared radiation for survival; they must warm themselves in the sun to become active.
5. A hot sidewalk would be glowing brightly and the cool grass would look dark.

What would you say?

6. c 7. a 8. b 9. d 10. c



Unit Assessment

What do you know about Infrared Radiation?

Write the answers to these questions in your journal or on a separate sheet of paper.

Think about it

1. How could you tell if someone had a fever by using an infrared camera?
2. How would you make yourself look invisible to an infrared camera?
3. Can you think of any new uses for an infrared cameras?
4. What kind of animals depend on infrared radiation for survival?
5. What would a sidewalk and a nearby lawn look like through an infrared camera on a sunny day?

What would you say?

6. The gray filament of an oven that is heating up would appear—
 - a. dark gray to an infrared camera.
 - b. red to an infrared camera.
 - c. nearly white to an infrared camera.
 - d. invisible to an infrared camera.
7. As the temperature of an object increases, the frequency of the infrared radiation it emits—
 - a. increases.
 - b. decreases.
 - c. stays the same.
 - d. decreases then increases.
8. A person hidden in smoke can be seen by an infrared camera unless—
 - a. it is a hot, summer day.
 - b. the smoke is at the same temperature as the person's body.
 - c. the camera is pointed directly at the smoke.
 - d. bright light is shining on the smoke.
9. A light bulb produces more infrared radiation than—
 - a. a toaster.
 - b. an oven.
 - c. a theater spotlight.
 - d. a fluorescent light.
10. Ultraviolet radiation is probably located on the electromagnetic spectrum—
 - a. between infrared radiation and visible light.
 - b. next to infrared radiation, on the other side from visible light.
 - c. above visible light, next to the violet end of the visible spectrum.
 - d. all the way at one end.



Activity 1

Focus on Radiation

If you can't see infrared radiation, how can it be measured? How is infrared radiation like visible light? How is it different? Is there an easy way to detect infrared radiation?

Getting Ready

Overview

Students find the focal distance for a small lens and then focus infrared radiation through the lens onto a thermometer. Students measure how removing the lens and moving it back changes the temperature.

Objectives

After completing this activity, students will be able to—

- discuss the relationship between visible light and electromagnetic radiation.
- describe the relationship between electromagnetic radiation and heat
- demonstrate how infrared radiation can be detected and measured

Time Needed

Preparation: Approximately 20 minutes

Classroom: Approximately 45 minutes

Materials

For the teacher:

- slide projector
- large prism
- diagram of the electromagnetic spectrum

For each group of students:

- 3 ring stands with clamps
- common 16d iron nail
- 5 cm focal length lens
- thermometer
- modeling clay to hold the thermometer in the clamp
- Bunsen burner

Important Terms

electromagnetic spectrum — The entire known range of electromagnetic radiation.

frequency — The number of times an electromagnetic wave oscillates each second. The frequency of a light wave determines its color.

infrared radiation — The portion of the electromagnetic spectrum with a frequency less than that of visible light and greater than that of radio waves.



Infrared

Here's How

Video Clip 1

47:14 to 49:02 David Heil and Dr. Paul Kruse take a look at infrared radiation.
(1 min. 12 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [46:28 to 47:11]. Find out what students already know about infrared radiation. As a class, discuss the questions posed by Eileen Galindo.
- Caution students to follow established classroom safety procedures when working with the Bunsen burner and red-hot nail.
- Lenses with a 5 cm focal length can be obtained from most science equipment supply companies.
- It helps to blacken the silver bulb of the thermometer with a washable marker. This will allow it to absorb more infrared radiation.
- Heat sensitive strips made from thermochromic liquid crystal may replace thermometers in this activity. They may be obtained from the Exploratorium store in the form of postcards or from Edmonds Scientific. You should purchase strips that turn red at 80°F.
- Students may wish to set up other variables to test the flow of infrared radiation, such as blocking the lens with a sheet of paper.
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on infrared radiation after completing this activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the student experiments.
- Set up the slide projector and prism.
- Make copies of Activity Sheet 1 for each student.
- Review the information in the Background on page 24.

Engage (Approx. 15 minutes)

Before class, set up the slide projector and prism. Place the prism about a foot in front of the projector so that the light passes through it and forms a bright spectrum on a nearby wall. Begin class by dimming the lights and having students observe the spectrum. Ask students where the colors come from. (They are part of the white light.) Where in nature do we see these colors? (a rainbow) Explain that the colors in the spectrum make up all of the electromagnetic radiation that the human eye can sense. Lead the students to a discussion about the portion of the electromagnetic spectrum that isn't visible to the human eye. Find out if they are familiar with other forms of electromagnetic radiation: radio waves, microwaves, ultra-violet radiation, infrared radiation, X-rays, and gamma rays.

Show students a diagram of the electromagnetic spectrum. (A diagram of the spectrum can be found at Resource Button A on the CD-ROM.) Discuss the different forms of electromagnetic radiation in the spectrum. Point out that visible light is only a very small part of the spectrum. Play Video Clip 1 [47:14 to 49:02]. Discuss Sir William Hershel's famous experiment. Ask students about other ways that they could verify the existence of infrared radiation. (They can feel heat from an object even though it appears normal—not glowing hot, etc.)

Explore (Approx. 45 minutes)

Explain that students can detect infrared radiation in ways that can be measured.

Students should work in small groups. You may wish to set up the ring stands with thermometers and lenses in advance. Use the illustration on Activity Sheet 1 as a reference. Students are going to focus infrared radiation through a lens onto a thermometer. Students should follow these directions for the set-up:

- Clamp a 16d nail to a ring stand so that the nail head can be heated by a Bunsen burner.
- Attach a 5 cm focal length lens to a second ring stand. The lens should be approximately the same height as the nail head.
- To a third ring stand, clamp a thermometer so that the bulb is at the same height as the lens and nail head. The nail head, lens, and thermometer should form a straight line. Approximately 5 cm (2 in) of space should be between the nail and the lens and 5 cm between the lens and the thermometer. The optimum position depends on the exact focal length of the lens.



Activity 1

- Hold a flashlight by the nail head and hold a sheet of paper by the thermometer bulb. Shine the flashlight through the lens. Adjust the location of the flashlight and paper until the light beam is focused on a sheet of paper. Adjust the thermometer so that the bulb is at the exact focal point.
- On the ring stand, mark the location of the lens clamp. Move the clamp about 15 cm (6 in) up or down the ring stand so that the lens is no longer between the nail and the thermometer.
- Light the Bunsen burner and heat the nail head until it is red hot.
- Record the temperature on the thermometer.
- Move the lens back to its original position so that the focal point is again on the thermometer.
- After several minutes record the temperature on the thermometer.
- Move the lens up or down the ring stand again and record the temperature after several minutes.

When the infrared radiation is focused on the thermometer, the temperature should be several degrees higher than when the lens is moved away. After all groups are finished, discuss the results of the activity. Ask how much temperature variation students observed. Was the range the same for all groups? What might have caused the differences in ranges from group to group? Discuss what the experiment reveals about how heat travels.

Evaluate

1. A piece of metal is so hot it glows yellow. As it cools, it turns red and finally stops glowing. Is it still hot? Explain. (Yes, it's still hot. While the metal is too cool to emit electromagnetic radiation in the visible spectrum, it is still emitting infrared radiation, so it is still hot.)
2. Could infrared radiation have been discovered before the invention of the thermometer? Why or why not? (Yes; the discovery required that someone notice that the area beyond the red end of the visible spectrum is warmer. Being able to measure temperature and seeing a spectrum with a prism helped scientists understand and quantify the effect.)
3. The lamp of a slide projector converts electrical energy into light energy. Does it do it efficiently? Why or why not? (No; the bulb produces a fair amount of heat—infrared radiation—that is not necessary for viewing slides.)

Try This

Research Sir William Hershel's famous experiment. Using a prism, a thermometer, and sunlight, measure the temperature along the spectrum of visible light. Compare it to the temperature just beyond the red. Record your observations and data. Report your findings to the class.

Obtain three light bulbs—standard incandescent, fluorescent, and halogen—that shine with comparable brightness. Which one emits more infrared radiation? Which one is more energy efficient? Devise an experiment that will answer these questions. Collect data and analyze it. Report your findings to the class.



FOCUS ON RADIATION

Activity 1 Sheet

NAME _____

CLASS PERIOD _____

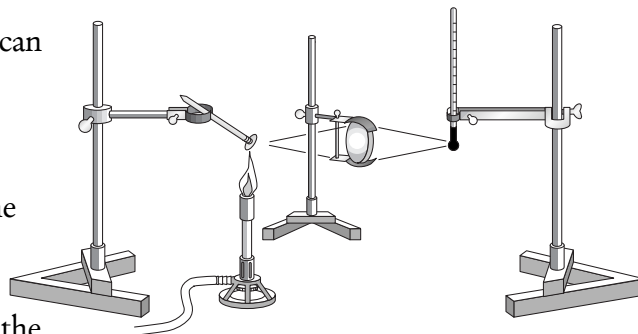
WHAT YOU'RE GOING TO DO.

You're going to explore how infrared radiation can be focused and measured.

HOW TO DO IT

Work with your group.

1. Clamp a 16d nail to a ring stand so that the nail head can be heated by a Bunsen burner.
2. Attach a 5 cm focal length lens to a second ring stand at the same height as the nail.
3. To a third ring stand, clamp a thermometer so that the bulb is at the same height as the lens and nail head. The nail head, lens, and thermometer should form a straight line. Approximately 5 cm of space should be between the nail and the lens and 5 cm between the lens and the thermometer.
4. Hold a flashlight by the nail head and hold a sheet of paper by the thermometer bulb. Shine the flashlight through the lens. Adjust the location of the flashlight and paper until the light beam is focused on the sheet of paper. Adjust the thermometer so that the bulb is at the exact focal point.
5. On the ring stand, mark the location of the lens clamp. Move the clamp about 15 cm up or down the ring stand so that the lens is no longer between the nail and the thermometer.
6. Light the Bunsen burner and heat the nail head until it is red hot.
7. Record the temperature on the thermometer.
8. Move the lens back to its original position so that the focal point is again on the thermometer. Record the temperature on the thermometer every minute for five minutes.
9. Move the lens up or down the ring stand again and record the temperature every minute for five minutes.



RECORDING YOUR DATA

Record these variables in a table in your journal, along with any other observations you make during the experiment.

Beginning temperature reading _____

Temperature reading with lens:

Minute 1 _____ Minute 4 _____

Minute 2 _____ Minute 5 _____

Minute 3 _____

Temperature reading with lens removed:

Minute 1 _____ Minute 4 _____

Minute 2 _____ Minute 5 _____

Minute 3 _____

WHAT DID YOU FIND OUT?

What was the range of temperatures you recorded?

What effect did the lens have on temperature? How do you explain this?

What might be another way to test for infrared radiation?

Compare your data with the data of other groups. What might account for any differences?



Activity 2

Infrared Ray Gun

How does a remote control work? What kind of signal does the remote control use to communicate with the TV? How is an infrared remote control similar to a flash light? Can infrared radiation pass through glass like visible light does?

Getting Ready

Overview

Students use an infrared remote control to compare the characteristics of infrared light and visible light. Students also investigate reflection and transmission of infrared light.

Objectives

After completing this activity, students will be able to—

- describe physical laws that infrared radiation obeys
- discuss the practical aspects of an infrared remote control
- design a similar experiment relying on different properties of electromagnetic radiation.

Time Needed

Preparation: Approximately 20 minutes

Classroom: Approximately 40 minutes

Materials

For each group of students:

- penlight flashlight
- mirror
- infrared remote control and the television or VCR it controls
- piece of black poster board
- pane of glass

Important Terms

digital signal — A series of electric or light pulses.



Infrared

Here's How

Video Clip 2

51:04 to 53:17

David Heil and Paul Kruse discuss practical applications of infrared radiation. (2 min. 13 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the materials for each team of students.
- Set up the televisions and remote controls.
- Test the remote controls and penlight flashlights to make sure they work.
- Make a copy of Activity Sheet 2 for each student.
- Review the information in the Background on page 24.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [46:28 to 47:11]. Find out what students already know about infrared radiation. As a class, discuss the questions posed by Eileen Galindo.
- Make sure that none of the edges of the glass pane are sharp. If they are, cover them with masking tape. Remind students to handle the glass carefully.
- This activity will be more successful if you can darken the room to make the light from the flashlight more visible.
- If possible, the first step could be done with the flashlight—and later the remote control—resting on a desk or table. However, this requires that the TV's remote sensor be at the same height.
- If only one television and remote control are available, split the class into larger groups and assign a single experiment to each group.
- If any students have any respiratory problems, they should avoid breathing in concentrated airborne talc.
- If it is appropriate, view the entire *Newton's Apple* video segment on infrared after completing the activity.

Engage (Approx. 10 minutes)

Hold up a TV remote control and ask the students what it is. Ask them if they know how it works. Encourage them to develop and discuss different theories.

Ask students if they can think of some other practical applications for infrared radiation. Play Video Clip 2 [51:04 to 53:17]. Discuss some of the applications shown in the clip. Remind the students that infrared radiation is a form of electromagnetic radiation. It is exactly like light, except it has a lower frequency. Ask the students how they might determine if the infrared radiation coming out of a remote control behaves in the same way that light does.

Ask the students if they have remote controls at home. Does the remote control have to be pointed directly at the TV to change channels? (*no*) Have the students give suggestions as to how the remote control might work without being pointed directly at the TV.

Have the students discuss the properties of light. What do they know that light does and doesn't do? Ask them to suggest ways that they could test infrared radiation to see if it does or doesn't do the same things. Suggest using a remote control as a source of infrared radiation.

Explore (Approx. 40 minutes)

Tell students they are going to experiment with a remote control and a flashlight to see how infrared radiation is similar to or different from light.

Students work in small groups. Each group should select an experimenter, a facilitator, and a data recorder. One or more students in the group can set up each of the activities.

Students find the remote sensor on the front of the television. Then they prop the poster board up in front of the TV, and make a mark on the part of the posterboard that covers the sensor.



Activity 2

Students prop the mirror up on a chair or desk, facing the TV. The experimenter aims the pencil flashlight at the mirror so the reflection of the light beam strikes the poster board exactly on the mark. The experimenter does not move. The facilitator takes the flashlight out of his or her hands, and replaces it with the remote control. The experimenter aims the remote control at exactly the same place. The facilitator removes the poster board, and the experimenter presses a button on the remote control.

Next, students exchange the roles of experimenter and facilitator. They place the remote control and the flashlight on a desk, pointed in the same direction. Both should be aimed at the TV. The facilitator places the poster board in front of the TV, then holds the pane of glass in front of the flashlight. The experimenter turns on the flashlight. The recorder notes whether the flashlight beam travels through the glass. The facilitator then removes the poster board, and the experimenter presses the power button on the remote control. The recorder notes whether the infrared beam travels through the glass.

Discuss the results of the activity. Ask team members whether the infrared beam reflected off the mirror in the same way the light beam did. (*yes*) Did any substances block the light beam but not the infrared beam? (*yes, the talcum powder*) Have students discuss why this might be. Remind them that infrared radiation is exactly like visible light, except it has a lower frequency.

Evaluate

1. The TV in one room is hooked up to a VCR in the next room. How could you use the remote control to fast forward the VCR while you sat in front of the TV? (by setting up a mirror that would reflect the infrared beam onto the VCR's remote sensor)
2. Why doesn't a remote control use a beam of visible light instead of a beam of infrared radiation? (Infrared light is invisible. If a remote control used visible light, turning on a light in the room could activate the television.)
3. How might you have determined whether infrared radiation will pass through glass without using a remote control? (Answers will vary. Possible answer: Place a thermometer just inside a window and another one just outside the window. Compare the readings.)

Try This

Try the same activity and shine the beams of visible and infrared light through a puff of talcum powder. What are the results?

Explore the reflection of light and infrared radiation in more depth. Set up the mirror, flashlight, and poster board on a desktop covered with paper. The flashlight should reflect off the mirror and onto the poster board. Draw lines to represent the angle of the light beam approaching the mirror and leaving the mirror. Repeat with the flashlight at different angles. What rule can you discover?

Test the remote control and the flashlight further. Try blocking the beams with other materials, such as tracing paper, construction paper, clear plastic, etc. Can you find a material that blocks the light beam, but not the infrared beam? Can you find a material that blocks the infrared beam, but not the light beam?

Research other practical uses of infrared technology. Report your findings to the class.

INFRARED RAYGUN

Activity Sheet 2

NAME _____

CLASS PERIOD _____

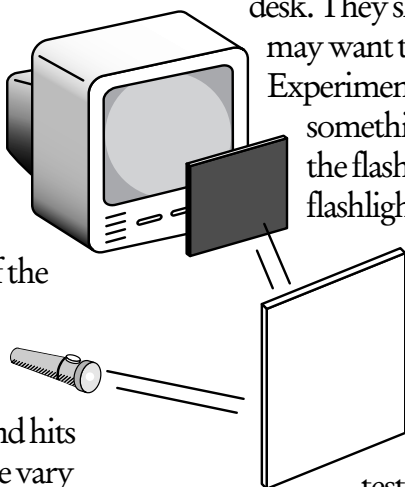
WHAT YOU'RE GOING TO DO

You're going to test an infrared beam and a light beam under similar circumstances to see how they're the same and how they're different.

HOW TO DO IT

1. Work with your group. Select an experimenter, a facilitator, and a data recorder. Gather the materials needed for the activity.

2. Prop the mirror up on a desk or table. Make sure it's facing the television. Place the poster board in front of the TV and mark the spot directly in front of the TV's remote sensor. Experimenter—Aim the flashlight so that the beam reflects off the mirror and hits the mark on the poster board. Then be very careful not to move. Once the remote control is in your hands, aim it in the exact same direction and press the power button. Facilitator—Once the experimenter has aimed the flashlight properly, carefully take it from his or her hand. Place the remote control in the experimenter's hand in exactly the same position. Then take the posterboard away from the TV.



3. Place the flashlight and the remote control on a desk. They should both be pointed at the TV. You may want to tape them down.

Experimenter—Each time the facilitator places something between the devices and the TV, test the flashlight, then the remote control. Turn the flashlight on and then off. After the facilitator has removed the poster board, press the power button on the remote control.

Facilitator—First hold the pane of glass between the devices and the TV. Make sure the posterboard is in front of the TV when the experimenter tests the flashlight, and that it isn't there when the experimenter tests the remote control.

Data Recorder—For each test, record whether the light beam and the infrared beam passed through the substance that was blocking it and reached the target.

RECORDING YOUR DATA

Set up a table like this one in your journal, and record the following information.

Blocking substance: _____
 Light beam: passed _____ didn't pass _____
 Infrared beam: passed _____ didn't pass _____

Other observations:

WHAT DID YOU FIND OUT?

How are infrared and regular light similar?

How are infrared and regular light different?

Did your results match those of other groups?
 What might account for any differences?

What are some other ways you might test the properties of infrared radiation?



Activity 3

As Clear As Glass

Why do plants grow in a greenhouse during the winter? What happens inside a car with rolled-up windows on a sunny day? Does sunlight always pass through glass? Does infrared radiation from the sun always pass through glass? What is the greenhouse effect?

Getting Ready

Overview

Students compare the transmission of infrared radiation through a pane of glass with the transmission of infrared radiation in and out of a closed glass container.

Objectives

After completing this activity, students will be able to—

- conduct an experiment using a control and analyze the results
- discuss how wavelength affects the transmission of infrared radiation
- explain why plants can grow in greenhouses in cold weather.

Time Needed

Preparation: Approximately 10 minutes.

Classroom: Approximately 70 minutes.

Materials

For each group:

- 3 thermometers
- small pane of glass
- wide-mouthed glass jar large enough to completely hold and enclose one of the thermometers

Important Terms

greenhouse — A small glass building in which plants are grown.



Infrared

Here's How

Video Clip 3

50:08 to 51:04

Maj. Matt Ferrin shows film of moving vehicles taken through an infrared "thermal sight" on a tank. (56 sec.)

Video Clip 4

49:02 to 50:03

David Heil and Paul Kruse discuss infrared radiation, visible light, and the electromagnetic spectrum. (1 min. 1sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [46:28 to 47:11]. Find out what students already know about infrared radiation. As a class, discuss the questions posed by Eileen Galindo.
- Make sure that none of the edges of the glass pane are sharp. If they are, cover them with masking tape. Remind students to handle the glass carefully.
- If the sun is not shining on the classroom's window sill, you can have students place their setups under lamps containing 100-watt or 150-watt bulbs. All three thermometers should be an equal distance from the bulb, and as close as possible to it. Even if the window sill is sunny, you might have one or two groups use lamps instead, then compare the results of the various groups.
- If it is appropriate, view the entire *Newton's Apple* video segment on Infrared after completing the activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 3 for each student.
- Review the information in the Background on page 24.

Engage (Approx. 10 minutes)

Hold your hand near a sunny window or a burning light bulb. Ask students to explain why you feel heat. (Infrared radiation from the sun or from the bulb is striking your hand, and you feel it as heat.)

Show Video Clip 3 [50:08 to 51:04]. Ask why the vehicles show up so brightly on the infrared viewer. (Objects that are hot show up brightly, and the vehicles are producing a lot of heat.) Have students recall what happens inside a car parked in the sun with the windows rolled up. Have students tell why this might happen. Is it for the same reason that the vehicles in the video were hot? (No, because those vehicles' engines were running. A car in a parking lot is not producing heat, it's being heated by infrared radiation from the sun.) What would happen in the same car with the windows rolled down? (It wouldn't get as hot.) Why? Begin a discussion as to what role the window glass plays in the heating of the car.

Ask students to think of a greenhouse. Plants can grow in a greenhouse in the winter, because the interior of the greenhouse stays quite warm. The glass in the greenhouse serves the same purpose as the windows in the car. Play Video Clip 4 [49:02 to 50:03]. Lead students to understand that all objects emit infrared radiation, but that hotter objects emit more infrared radiation, and radiation with a higher frequency. Have students discuss how that fact, combined with the properties of glass, might allow a greenhouse to heat so well.

Explore (Approx. 60 minutes)

Tell students they are going to experiment with glass to determine how it affects heating.

Students work in small groups. Each group should select a data recorder. One or more students in the group can set up the activity. Each group should be assigned a section of window sill.



Activity 3

If possible, students should open the window slightly, so the glass in the window does not affect the experiment. Students first place one thermometer on the window sill. Then they prop the pane of glass up in the window opening. They should place the second thermometer so that sunshine must pass through the pane of glass to reach it. Students place the third thermometer inside the glass jar and invert it on the window sill. All three thermometers should be at about the same angle to the sun.

The recorder notes the reading on all three thermometers at the beginning of the experiment. He or she then rechecks the readings every five minutes for an hour.

Discuss the results of the activity. Ask team members which thermometer registered the highest temperature. (the one in the jar) Did the presence of glass alone affect the reading of the thermometers? (The thermometer behind the pane of glass may have read slightly higher than the first thermometer, but it wasn't nearly as high as that of the thermometer inside the jar.) Have students discuss why the glass jar caused a much greater increase in temperature than the pane of glass.

Ask whether infrared radiation from the sun can penetrate the glass. (yes) What happens when that radiation strikes the thermometer and the air around it? (They get warmer, so they emit more infrared radiation.) How is infrared radiation from the sun different from infrared radiation emitted by the thermometer and the air around it? (Infrared radiation from the thermometer is weaker and has a lower frequency.) How might that account for the higher temperature inside the jar? (The low-frequency infrared radiation cannot penetrate the glass, so it stays inside the jar, increasing the temperature.)

Evaluate

1. What purpose did the first thermometer serve in this experiment? (It was a control to show the temperature with no glass involved, in order to provide a basis for comparison.)

2. A group of scientists is setting up an experiment involving low-frequency infrared radiation. The lab is refrigerated, so only the apparatus will produce much infrared radiation. They need to make sure that no low-frequency infrared radiation enters the lab and confuses their readings. The lab has a window. Do they need to block it off? Why or why not? If they do, what should they use? (They don't need to block the window off, because low-frequency infrared radiation does not penetrate glass.)

3. How does a greenhouse keep plants warm in the winter? (High-frequency infrared radiation from the sun enters the greenhouse. It is absorbed by the air, the plants, the dirt, and the floor, making them warmer. They emit an increased amount of low-frequency infrared radiation. This radiation cannot penetrate the glass, so it stays in the greenhouse. It is re-absorbed by the air, the plants, the dirt, and the floor, making them even warmer.)

Try This

Repeat the experiment using glass bottles and jars of different colors. Which color traps the most infrared radiation inside? Test other materials, such as transparent plastic and opaque plastic.

As certain gases build up in the atmosphere, they change the properties of the atmosphere. Specifically, they change the way the atmosphere lets certain frequencies of radiation through, and doesn't let others through. This is sometimes called the Greenhouse Effect. Describe, based on this experiment, how you think the Greenhouse Effect works. Check your answers by doing research on the Greenhouse Effect.

Invite the manager of a local greenhouse to speak to the class about how the greenhouse works.



AS CLEAR AS GLASS

Activity Sheet 3

NAME _____ CLASS PERIOD _____

WHAT YOU'RE GOING TO DO

You are going to test how infrared radiation passes through glass in different situations. Which one gets the hottest?

HOW TO DO IT

Work with your group. Open the window so the sun shines on the sill without passing through the window glass. Place a thermometer on the window sill. Prop a pane of glass up in the window opening and place a second thermometer behind it. Sunlight should pass through the glass to reach the thermometer. Place a third thermometer in a glass jar with a lid and set it on the window sill.

Data Recorder — Record the temperature on all three thermometers as soon as they are put in place. Check and record the temperatures every five minutes for an hour.

RECORDING YOUR DATA

Set up a table like this one in your journal, and record the following information:

Readings at ____ minutes into experiment.

Thermometer #1: ____ degrees

Thermometer #2: ____ degrees

Thermometer #3: ____ degrees

WHAT DID YOU FIND OUT?

Which thermometer showed the greatest increase in temperature?

Did infrared radiation from the sun penetrate the glass? How do you know?

How was the setup in front of the pane of glass different from the one inside the jar?

What does this tell you about high- and low-frequency infrared radiation?

Graph your data. Does this help you analyze your results?



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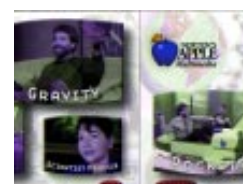
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